A Web-based Virtual Patient to Support Reflective Learning

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Abstract. Simprac is web-based virtual patient simulation for the diagnosis and management of chronic illness. Users have the opportunity to manage patients over a series of consultations that vary, based on the management plan selected at the end of each consultation. Chronic illness is frequently a complex problem with multiple, and often competing, priorities and such an ill defined knowledge space might well be suited to reflective learning. By allowing the learner to compare their activity from the corresponding user model for their peers and experts it is hoped that learner reflection is encouraged.

1 Introduction

Medical practice, like other professions, involves learning through the whole of working life [1]. This has traditionally involved modalities such as rounds, educational meetings, conferences, refresher courses, seminars, lectures, workshops, and symposia. Unfortunately, these modalities are often ineffective in mediating improvements in patient care through changes in physician behaviour [2]. On the other hand, "interactive CME [continuing medical education] sessions that enhance participant activity and provide the opportunity to practice skills can effect change" [2]. This has led us to explore the potential role of simulation-based teaching systems to support long-term learning for medical practitioners.

With previous medical case simulations, computer based or otherwise, it has been consistently observed that there is considerable case specificity [3,4]. That is, medical practitioners or students may be able to perform one case well but do poorly on a different, but not altogether different, case. Based on their studies of simulations using trained actors, Elstein, Shulman and Spafka [5] found that the differences between the experts and the weaker problem solvers was to be found in the detail of their cognitive models consequent upon their experience. Anderson, Reder and Simon [6] suggest that optimal learning occurs when a combination of abstract and situation-specific training is provided and that abstraction promotes the transfer of knowledge and thus insight from one situation to another. In the context of a simulation-based learning system, this means that we should take care to go beyond a pure simulation of one or more cases. In light of these findings, we have developed web-based patient simulation, and attempted to include elements that encourage the practitioner to reflect on each case, evaluate their performance in meaningful ways, and abstract broadly from the particular learning

experience. It is hoped that by doing so, some issues related to case specificity might be addressed.

Most computer simulations have been developed with an emphasis on medical diagnosis and have generally involved a single patient encounter. In contrast, much patient morbidity is associated with the diagnosis and management of chronic disease such as diabetes mellitus and cardiovascular disease. These chronic disorders evolve over time and involve multiple doctor - patient encounters. The simulation we have been developing explores this chronic disease model by enabling the user / health professional to review the patient over a number of consultations with the patient outcome for the following consultation being defined by the management strategy chosen by the practitioner.

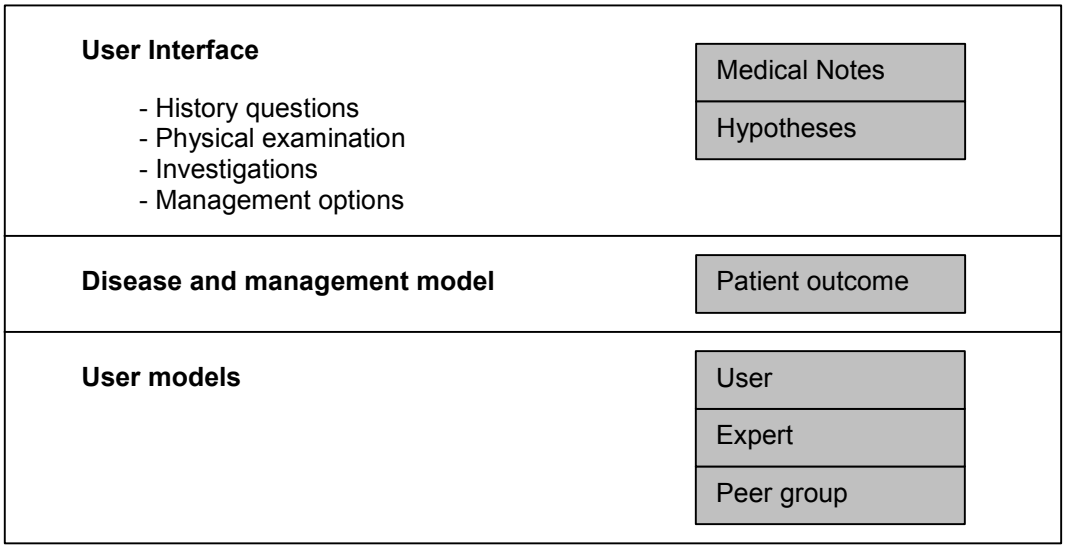

Figure 1: System overview. The simulation is comprised of three major components including the user interface, disease and management model, and the user models. Items in grey represent interface elements designed to support reflection.

In keeping with constructivist theories, Schön holds that professional knowledge involves a degree of artistry that can only be developed through practice within an appropriate context [7]. This can be delivered through a reflective practicum with maximum learning taking place where there is reflection on the actions undertaken. Thus he promotes the central idea of reflection as the means by which the student and practicing professional can maximise learning. These ideas are especially relevant to the often ill-structured nature of medical knowledge [5] and the difficulty in appreciating all the interacting factors that influence a patient's outcome that, in the case of chronic illness, may vary over time.

Kay [8] defines a user model as, "any individual, dynamic and explicit model the system holds about the user". Such models may, "represent the user's beliefs and preferences as well as other user attributes" [8]. Recent research has explored how opening the user model to the user can be used support reflection and improve knowledge of the content and structure of a domain [9]. These open learner models can range from the relatively simple to those that are quite sophisticated, where the user is not only able to view or discuss the user model, but modify it in a collaborative process [10].

An overview of the system is shown in Figure 1. As illustrated, there are three major components: the user interface, the disease and management model, and the user

models. While the simulation supports reflection at a number of points, this paper will focus on the role of the user model in supporting reflection. A brief description of the first case will be given, followed by a description of the user model and the interface used to provide users feedback on their actions. Preliminary evaluation results are then reported and finally, conclusions drawn.

2 The Case

The first case involves a 29 year old female, who has been referred for management of hypertriglyceridaemia. The patient has a known history of the rare disorder, Type 1B glycogen storage disease characterised by short stature, characteristic "doll like" appearance, fasting hypoglycaemia, neutropenia, hypertriglyceridaemia, hyperuricaemia, and hepatomegaly with abnormal liver function tests. At presentation, the hypertriglyceridaemia is at such a level that it places the patient at risk of developing pancreatitis. On the other hand, administration of an effective triglyceride lowering agent such as gemfibrozil is contra-indicated in the presence of liver disease. Type 1B glycogen storage disease is optimally managed by maintaining the fasting blood glucose

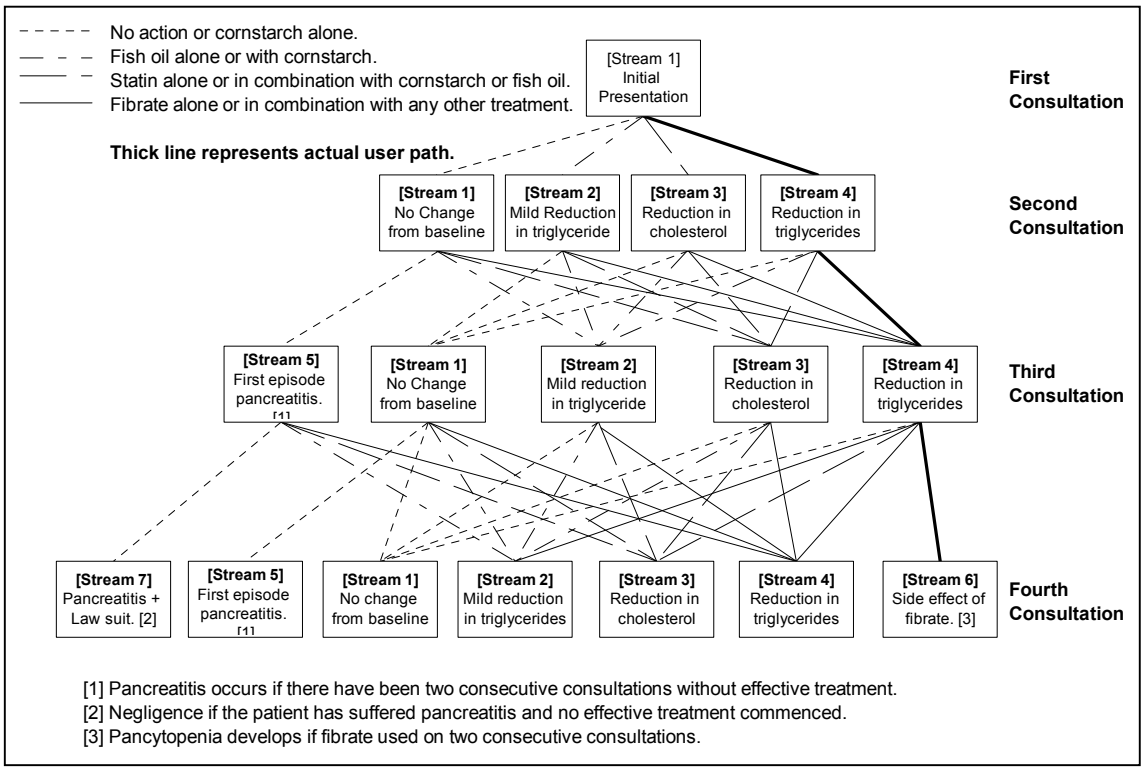

Figure 2: Case Overview. At the end of each consultation the actions selected by the user will determine which stream they enter at the next consultation.

level with the regular administration of cornstarch. With the exception of neutropenia, most of the metabolic derangements can be corrected by maintaining the blood glucose. Unfortunately, most patients have difficulty maintaining this therapeutic regimen. Thus, this case is typical of the complex issues facing the clinician, where one must balance the risks of treatment with the expected benefit. Moreover, these risks and benefits vary over time, and with respect to different individual's response to treatment.

As shown in Figure 2, users are able to traverse a series of consultations in a number of alternate ways. For example, at the end of the first consultation, if the user

doesn't provide any effective treatment they will enter stream one. Alternatively, if they elect to use a gemfibrozil they will enter Stream 4. The new stream the user will enter is determined by the management options selected by the user, and the current user stream. For example, at the end of the second consultation, if the user is currently in Stream One, and still does not provide effective treatment to lower the triglycerides, they will then enter Stream Five and be informed the patient has suffered an episode of pancreatitis. If, on the other hand, the user is in Stream Four, and then ceases the effective treatment, they will enter Stream One at the beginning of the third consultation.

3 The User Model

A relatively simple user model has been developed that is shown in Figure 3. Each user may be associated with multiple case episodes defined by the username, case and professional background. Thus a user may attempt any particular case from different professional backgrounds. For example, a user may choose to attempt the case as a medical student or a general practitioner. The choice of professional background currently determines the peer group against which a user may compare their activity as they complete each consultation, rather than the difficulty of the case presentation.

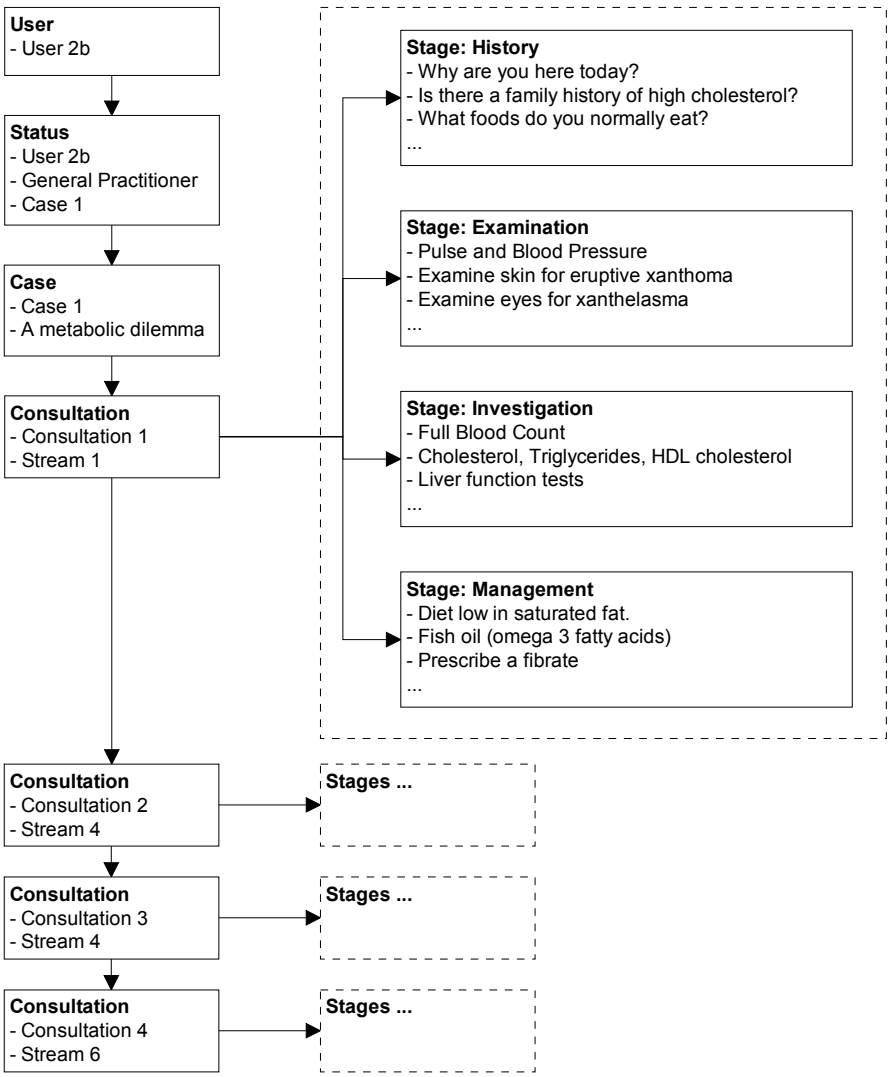

Figure 3: Simprac User Model. Each user, for any given professional background is able to undertake a case consisting of multiple consultations, each of which has four stages including history taking, physical examination, investigations and patient management.

Each case episode can have one or more consultations, defined by a consultation number and stream. Other than the first consultation, where only one stream is defined, there may be one or more parallel streams representing the different outcomes for the patient, dependant on the management actions selected during the previous consultation. Again, when an individual compares their activity to their peers or an expert, they are only shown the data for that consultation number / stream pair.

Each consultation is associated with up to four stages or activity types, denoted by the terms: history, examination, investigation, and management. History is that activity directed at asking the patient questions. Examination is physical examination of the patient. Investigation represents the use of available pathological, radiological and other services provided. Lastly, management covers those activities that are the central outcome of the whole process. It aims to modify the outcome for the patient, for example by treatment with medication or perhaps physical therapies etc. For each consultation the user may choose from none to many items within each stage and although most medical consultations will tend to follow a sequential pattern of history, examination,

investigation, and management there is no requirement to undertake any of these and they can be undertaken in any order.

For example, the student or practitioner might begin by asking the patient, “why have you come today?” To which the patient responds, “last week while at the shopping centre I had my cholesterol and triglyceride levels tested at the 'Healthy Heart' stand. They said my cholesterol at 6.4 mmol/L and triglyceride at 8.1 mmol/L were very high and suggested I see a doctor for advice”. In response to this answer the practitioner might then ask, “have you ever had your cholesterol or triglyceride levels measured previously?” In this case the patient would respond, “I have had high cholesterol and triglyceride since I was a child but they have never been this high before. The triglycerides have usually been between 2 and 4 mmol/L while the cholesterol has generally been less than 6 mmol/L. They were last checked over 12 months ago.” Having elucidated that the patient has a long standing history hyperlipidaemia, the practitioner would generally direct their questions at determining whether the hyperlipidaemia was a primary problem or secondary problem. In this case, the not uncommon, presenting complaint is secondary to a rare condition. Further questioning would also be directed at assessing how the underlying condition had been managed to date, and assessing whether any complications, such as recurrent infections, hyperuricaemia, or pancreatitis, associated with the metabolic derangements, have developed.

Once the history has been completed most practitioners would precede to physical examination with an initial evaluation of the vital signs including pulse and blood pressure. A student or practitioner might then inspect the limbs for xanthomata and the eyes for xanthelasma both of which may be seen in patients with hyperlipidaemia. As hypercholesterolaemia is associated with an increased risk of cardiovascular disease, a cardiovascular examination including such items as inspection of the neck for the jugular venous pressure, auscultation of the neck for carotid bruit, and auscultation of the heart for abnormal heart sounds, might be performed. Again, these examinations are directed at confirming the diagnosis and assessing the consequences of the disease process.

Having completed a relevant physical examination, a practitioner would then order investigations such as total cholesterol, triglyceride, HDL cholesterol, and liver function tests,again to confirm the diagnosis and to assess the consequences of the underlying condition. The doctor or student might also request a base-line creatine kinase estimation if it was envisaged that they would commence the patient on a fibrate or statin to lower the lipid levels. At this point, the user has the opportunity to return to another stage, such as history taking, if items have been overlooked or an unexpected finding was found in the examination or results of investigations.

Based on the information elucidated by the practitioner and their hypotheses about the condition under scrutiny, the practitioner will make their management decisions. In this particular case, if dietary interventions alone are used, there will be no change in the patient’s lipid profile and they will remain in stream one at the second consultation. If, however, a statin is prescribed with any other treatment other than a fibrate, there will be a modest improvement in the triglycerides but a more marked improvement in the cholesterol and the case will move to stream three. On the other hand, if a fibrate is prescribed, there will be a marked improvement in the triglycerides but a less significant improvement in the total cholesterol concentration and the case will move to stream four at the second consultation.

4 Consultation Review

The above model is then used at the end of each consultation to assist the user to reflect on what they have done in the most recently completed consultation. Using an interface to interact with the web-based application, the users are initially asked to classify whether the activities and actions they selected at each stage of the consultation, were critical, relevant or not relevant to the diagnosis or management of the virtual patient. The requirement for the users to classify their actions was only implemented for the last two evaluations. Having classified their actions, the user is shown a screen (Figure 4) that enables them to compare their activity with their peers or an expert, for each stage of the consultation. This data can currently be viewed as a bar, line or pie graph. For each stage of the consultation, including history taking, physical examination, ordering of investigations, and selection of management options, the user can obtain feedback on the questions they asked compared to an expert.

Figure 4 provides an example of the user interface. The number of questions asked when taking the patient history over three consultations is displayed. The bar

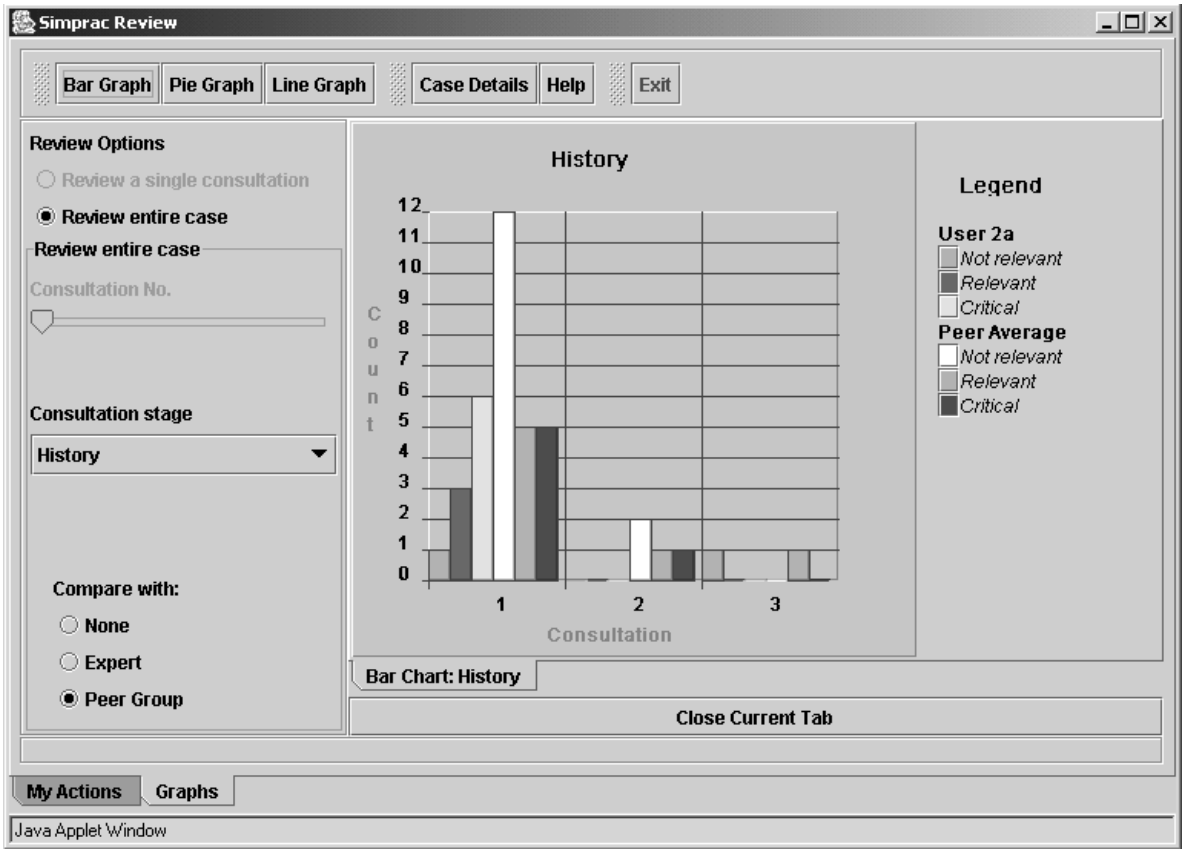

Figure 4: Simprac Review Interface. Three consultations are displayed comparing the user '2a' to the peer group. In the first consultation, the user has performed well compared to the peer group. Reading from the left in consultation 1 they asked, 1 irrelevant, 3 relevant and 6 critical questions compared to the peer average of 12, 5 and 5. No questions were asked by the user in the second consultation.

chart displays data for user '2a' compared to the peer group average. For each stage of the consultation, the user can see which of the items they selected were classified by the authors as critical, relevant, or not relevant. They are also shown which, questions, examinations, investigations, and management options the authors considered critical or relevant, but they did not select. This information can be obtained by right-clicking

with the mouse and selecting a menu item to display the actions in tabulated form. At the time of the displayed evaluation, the peer group contained only three individuals.

5 Preliminary Evaluation

Four evaluations have been undertaken by three individuals, one individual undertaking two evaluations. Subject one was not familiar with the field but was familiar with the design of the application. Subjects two and three were advanced trainees and expert in the management of hyperlipidaemia but unfamiliar with the design of the application. The evaluations were undertaken using a simplified think-aloud protocol [11].

Table 1: Evaluation Summary.

* The total duration of each evaluation is given in parenthesis. These totals are greater than the sum of the individual consultations due to the variable time between consultations.

	Consultation	**1**	**2**	**3**	**4**
User 1	Duration* (85 min)	47	16	3	NA
	Stream	1	1	3	NA
	Questions	41	3	1	NA
	Examinations	25	0	0	NA
	Investigations	8	5	4	NA
	Management	1	2	Ceased	NA
User 2a	Duration* (64 min)	48	2	2	NA
	Stream	1	1	4	NA
	Questions	10	0	1	NA
	Examinations	27	0	0	NA
	Investigations	10	3	2	NA
	Management	2	3	Ceased	NA
User 2b	Duration* (60 min)	31	9	3	13
	Stream	1	4	4	6
	Questions	5	1	1	0
	Examinations	32	0	0	17
	Investigations	9	5	3	2
	Management	1	3	4	4
User 3	Duration* (79 min)	69	NA	NA	NA
	Stream	1	NA	NA	NA
	Questions	30	Ceased	NA	NA
	Examinations	43	NA	NA	NA
	Investigations	16	NA	NA	NA
	Management	1	NA	NA	NA

A summary of the evaluations is given in Table 1. Only one evaluation included all four consultations, as the users were given the option of ending the case at a time they felt was appropriate, rather than being forced to undertake all four consultations. The first two evaluations were undertaken some months before the last two, and at that time, the review interface was not fully functional. In particular, there was no facility to show which questions, examinations, investigations, or management options were classified by the authors as being critical, relevant or not relevant to the diagnosis and management of the patient.

In all the user trials, the users were frequently unaware of some support functions until these were explicitly explained. For example, users can record their own notes relating to the current case, as one would for any patient medical record. However, the two users who were unfamiliar with the system both needed to have this feature demonstrated to them, before making use of it. Thereafter, the feature was used

extensively. Similarly, none of the subjects used the review interface until prompted to do so, even though the link labelled, "Review consultation" was given at the end of each consultation. Instead, they immediately proceeded to the next consultation. Once they started using the review interface, however, they were able to do so without difficulty.

Comments made by each of the subjects are summarised in Table 2. Only comments relating to the user model and reflection have been included. Comments regarding specific aspects of the interface implementation have been omitted.

Table 2: User comments for each evaluation.

User 1	• Would like to be able to see detail of which questions, examinations, investigations, and management actions were considered by the authors to be critical, relevant, or not relevant to the appropriate diagnosis and management of the patient.
User 2a	• Would like to be able to see detail of which questions, examinations, investigations, and management actions were considered by the authors to be critical, relevant, or not relevant to the appropriate diagnosis and management of the patient. • Did not like adding a probability to their hypotheses.
User 2b	• The subject indicated that they would like to investigate the outcome of alternate management strategies for each consultation. • Would like a case summary at the end of each consultation to know what the authors considered to be the "right" answer or answers. • User disagreed with the relevance scores attributed, by the case author, to some of the history questions and management options.
User 3	• User disagreed with some of the classifications given by the case author to some of the management options. They considered that the use of gemfibrozil should not be considered critical. • Did not wish to enter an hypothesis immediately after taking the history but before examining the patient. • Did not like adding a probability to their hypotheses.

6 Discussion

We have begun exploring whether a virtual patient simulation might be used for medical education and continuing professional development. A prototype web-based application has been developed to simulate the management of chronic illness over a number of consultations. Based on preliminary evaluation data, we have developed an application that, after some initial training, is easy to use and provides a reasonable approximation to an authentic activity.

We have designed a simple and concrete student model that enables the user to compare the relative importance of their actions against those of an expert user and their peer group. A more abstract model that examined the user's approach to diagnosis and management could have been developed. For example, a model might consider the user's ability to determine whether a presenting disorder was primary or secondary to some other pathology, or whether contraindications to a proposed management strategy had been adequately excluded. We have taken a concrete approach in the belief that the user will be able to relate more readily to the concrete actions rather than some abstract concept. Furthermore, this application was designed to provide a generic platform for presenting cases involving chronic disease. Given the complexity of the medical domain and the fact that particular questions, examinations, or investigations may be undertaken for more than one reason, and these reasons my vary between cases, then the complexity of authoring cases becomes prohibitive if the knowledge space is to be modelled in this way.

Based on the observation that users did not use a number of support functions, such as the medical notes and the consultation review interface, future trials will include a short tutorial. In this way, users should then be aware of all the functions of the application before beginning the first case.

The user model, while relatively simple, is used to provide feedback to the user and enable them to compare their activity with an expert in the field or a professional peer group. Unfortunately, at the time of these evaluations the users were not compelled to use the review tool. In most cases, they did not use it until it was suggested that they do so. However, when they did use the interface, they appeared to be able to do so without difficulty. For future evaluations, the users will be required to undertake a review at the end of each consultation.

There was considerable variation in the time taken for the users to work through the case. Certainly, some of this variation can be attributed to the different degrees of familiarity with the simulation interface. However, it is likely that there was also a contribution from the experience of each individual with the management of the problems present in the patient. User One was familiar with the simulation interface but has not been in clinical practice for some years, and was not familiar with the specific diagnostic and management issues pertaining to this patient. As can be seen from Table 1 this user took 47 minutes to complete the first consultation, took an extensive history, and performed a large number of examinations. Users Two and Three were both experienced in the management of lipid disorders and tended to ask fewer, but more directed questions. The more rapid progress of user Two at their second attempt is consistent with a learning effect. For all subjects, many more questions and examinations were performed in the first consultation than in subsequent consultations. This is to be expected, as the first consultation has a large diagnostic component, but subsequent consultations are primarily directed at assessing the outcome of previous management decisions and modifying the management plan accordingly.

Importantly, the review interface had less functionality during the first two evaluations. In particular, there was no ability for the users to know which of their questions, examinations, investigations, or management options were regarded as critical, relevant or not relevant. As indicated by the comments for the first two users in Table 2, this was considered to be an essential function. In response to this feedback, this feature was added to the interface and was available for the next two trials. It could be argued that the graphical presentation of the user model at the end of each consultation may be important for reflection: one important piece of evidence for this is, the fact that the subjects considered it an essential feature of the interface.

The more experienced clinicians had a similar level of experience in the management of hypertriglyceridaemia as the case author, but less knowledge of the appropriate management of Type 1B glycogen storage disease. In some instances, they disagreed with the case author on the appropriate relevance scores for some of the questions and management options. This is not particularly surprising since we distinguish just three categories of importance/relevance. Some questions and investigations will have contentious classifications, even among experts. (Perhaps particularly among experts!) This may make the construction of cases more complex. This is a cost that must be borne if users of the system are to be able to assess their own performance relative to others. We consider it important to distinguish these three categories of questions and investigations as a critical aspect if the student model's support for reflection.

This disagreement may suggest that, the provision of these relevance scores encouraged these users to reflect on their activity. On the other hand, there is a real

possibility that this is just due to their knowledge and experience: less experienced clinicians or medical students, may just accept the information at face value without reflecting on its merits.

From Figure 2 and Table 1, it can be seen that User 2b followed a path where the patient experienced an unfavourable outcome. The patient's production of red cells, white cells and platelets were inhibited in response to treatment with Gemfibrozil. However, it should not be interpreted that User 2 managed the patient badly. While abnormal liver function tests are a relative contra-indication to the use of gemfibrozil, the extent of the hypertriglyceridaemia was such that it placed the patient at risk of pancreatitis. In view of this risk, it is not unreasonable to trial the use of the drug while monitoring the patient closely. Importantly, pancytopenia is a known, but uncommon side effect of Gemfibrozil that can be looked for by monitoring the patient's full blood count. Thus, if the specific lesson regarding the side effects of Gemfibrozil was learned, it can hopefully be generalised to the problem of being a aware of drug side effects, even those that are less common.

At this point in time, there is a suggestion that the ability of the review interface to provide users feedback on their user model, and enabling them to compare their model to others may encourage reflection. However, much more work remains to be done. Further evaluations and data collection involving medical students and general practitioners will be undertaken in the near future.

Even at this early stage of our work, we see the availability of a simple user model as having considerable potential to support reflection. This can operate in absolute terms, where the user reflects on the consultation they have just completed. We also believe that the comparative form, where the user can see how they did compared with other users, will also be of value. We have chosen to make the user models, individual and collective, available as one of several mechanisms to support reflection. This offers the promise of linking the specifics of a single simulated case to broader skills in management of chronic illness.

7 References

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